AN INVESTIGATION OF THE SPECTRAL CONTENT OF A MODE-LOCKED PULSED CO_2 LASER

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The frequency width of a pulse train in a pulsed mode-locked CO_2 laser has been accurately measured by means of a Fabry-Perot interferometer. We succeeded in resolving the longitudinal mode structure. The results are in excellent agreement with the results of previous measurements of the line width under lasing conditions.

1. Introduction

For studying mode-locked pulses it is important to know the spectral content of a pulse, i.e. the number of longitudinal modes.

For c.w. systems this mode content can be easily measured by means of a Fabry-Perot interferometer. For pulsed systems, however, a very serious complication arises due to the frequency jitter between successive shots of the pulsed system. Our observations show that the centre frequency varies from shot to shot, so that scanning interferometry in a multi-shot experiment seems to be impossible.

In this communication we wish to report on a successful method to overcome this problem. We have added to the laser cavity a low-pressure c.w. CO_2 discharge section excited below laser threshold. This additional section with a small band width has a favourable influence on the gain of the longitudinal mode nearest to the central frequency of the gain medium. This mode is then build up and stabilized before the other longitudinal modes are amplified by the pulsed system [1]. This means that the jitter of the centre mode of the pulse train is eliminated. Since the power content of the low-pressure section can be neglected as compared to that of the high-pressure section, the final temporal pulse shape and energy is practically equal to that observed in the absence of a low-pressure section.

2 Experimental procedure

In a previous paper we reported on the behaviour of the line width in a CO_2 TEA laser under lasing conditions [2]. It was shown that the line width increases

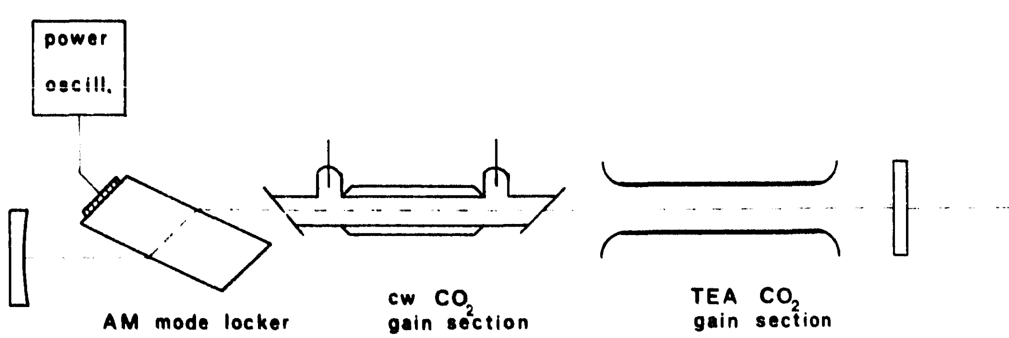

Fig. 1. The laser system.

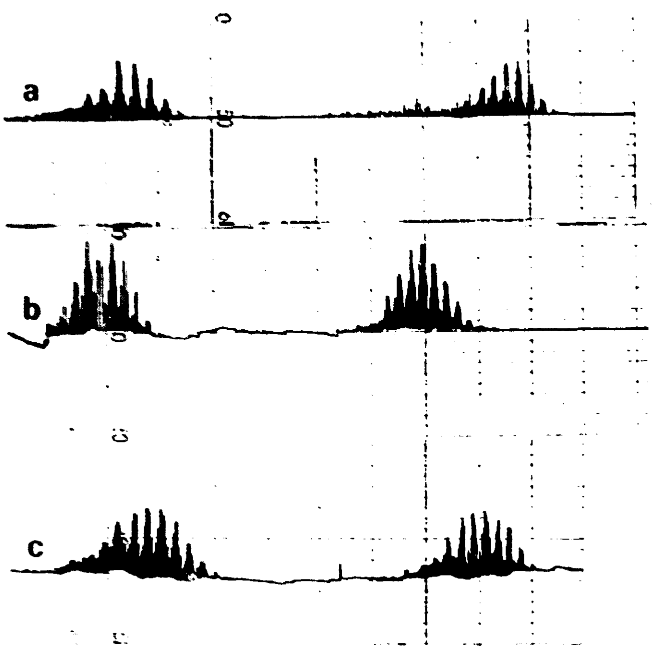

Fig. 2. Longitudinal mode structure for various gas mixtures as determined in our experiment. (a) 1:1:0 mixture, (b) 1:1:1 mixture, (c) 1:1:3 mixture.

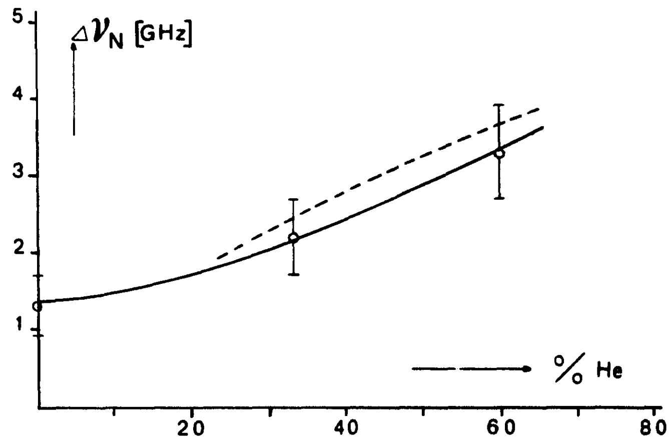

Fig. 4. Variation of the line width with He content in the laser gas mixture under lasing conditions. Solid line: best straight line fit to experiment described in this paper. Dashed line: results of detuning experiment.

with increasing helium percentage. These results were obtained by detuning measurements.

For a further investigation of the dependence of line width on helium content we also wanted to measure the frequency band width of the pulse train. From these measurements the line width can be deduced.

The experimental arrangement was similar to that described in ref. [3], except that we have inserted a c.w. CO_2 section into the TEA laser cavity, as shown in fig. 1.

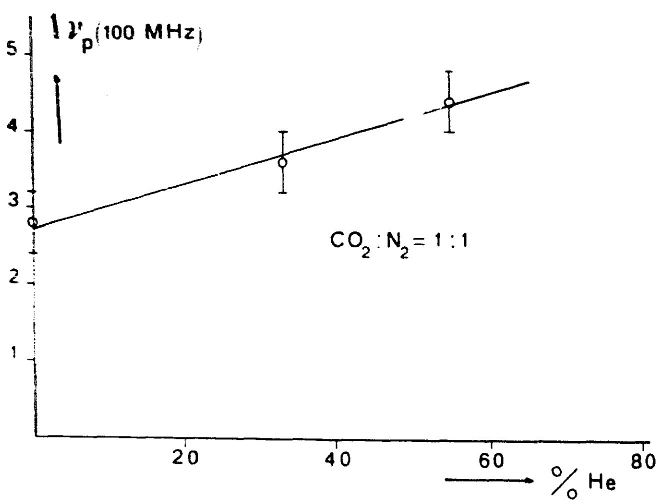

Fig. 3. Variation of the frequency band width of mode-locked pulses with He content.

In order to be able to measure the discrete longitudinal mode structure of the pulse train we used a scanning Fabry-Perot interferometer with a cavity length of 7.5 cm. Consequently the free spectral range is 2 GHz. To increase the transmission and the finesse of the interferometer we used a spherical cavity and applied mode matching to the set-up, consisting of the laser and the interferometer [4].

The interferometer was aligned by means of a c.w. CO_2 laser and its finesse was measured to at least 80.

The measurements were done by scanning the F.P. over the entire free spectral range within 1000 s, while the repetition rate of the TEA laser was about 1 Hz.

The output of the F.P. in this multi-shot experiment was detected by a thermocouple, the response of which was recorded by means of a penwriter.

3. Measurements

Our method of measuring the spectral content of a pulsed mode-locked CO_2 laser turns out to be very reliable. This is confirmed by measuring the pulse duration τ_p, and taking the product $\tau_p \cdot \Delta\nu_p$, where $\Delta\nu_p$ has been derived from the measured spectral content of the pulsed mode-locked CO_2 laser. For all measurements we found $\tau_p \cdot \Delta\nu_p = 0.41 \pm 0.04$. Ref. [2] predicts that $\tau_p \cdot \Delta\nu_p$ should be 0.44 for an AM mode-locked laser, which is in good agreement with our experiment. Furthermore we were able to distinguish the single longitudinal modes, as can be seen in fig. 2.

We have measured the variation of band width of the pulse train with helium content in the laser gas mixture. The ratio of CO_2 content to N_2 content was kept constant and equal to 1 for the various gas mixtures. The results are shown in fig. 3.

From these measurements we can easily calculate the line width $\Delta\nu_N$. It is shown in ref. [2] that a homogeneously broadened laser, locked with an intracavity amplitude modulator, should exhibit a frequency band width of the pulses of

$$\Delta\nu_{\mathrm{pulse}} = (\ln 2)^{1/2}\left(\frac{2m\alpha_a}{G_0}\right)^{1/4}(\Delta\nu_N\nu_m)^{1/2}, \qquad (1)$$

where G_0 is the saturated single-pass gain of the laser, α_a is related to the modulation depth, m is related to the continuous loss of the modulator and ν_m is the modulation frequency. In our case we have: $m = 0.05$, $\alpha_a = 0.4$, $G_0 = 0.35$, $\nu_m = 8 \times 10^7$ Hz.

The results are shown in fig. 4, which also shows the line width $\Delta\nu_N$, determined by means of the detuning measurement.

4. Discussion

The results of the experiment described in this paper and the results of the detuning experiment are in good agreement with each other.

The measurements of the frequency band width of a pulsed mode-locked laser confirm that the line width does indeed increase with increasing helium percentage.

References

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